Physics 3AB

Motion and Forces
Test One
2014

Name: Solutions

Mark: / 53

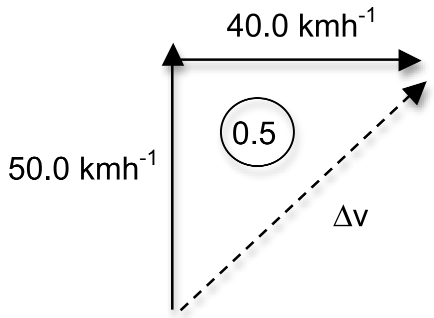
= %

Notes to Students:

- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
- **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(4 marks)**

A car moves due west with a speed of 40.0 kmh^{-1} and then turns and accelerates to travel north with a speed of 50.0 kmh^{-1}. With the aid of an appropriate diagram, calculate the change in velocity of the car.



$\Delta v = v - u$ (0.5)

$|\Delta v| = \sqrt{40^2 + 50^2}$ (0.5)

$= 64.0\ kmh^{-1}$ (0.5)

$\tan\theta = \dfrac{opp}{hyp}$

$= \dfrac{40}{50}$ (0.5)

$= 38.7^\circ$ (0.5)

$\Delta v = 64.0\ kmh^{-1}\ N38.7^\circ E$

(0.5) (0.5)

Question 2 **(3 marks)**

A cricket player, attempting to stop a ball from reaching the boundary, slides to a stop on level ground. Using energy considerations, calculate the distance an 85.0 kg player will slide, if his initial speed is 7.00 ms^{-1} and the force of friction against him is a constant 450 N.

$W = \Delta E_K$ (0.5)

$E_k = \frac{1}{2}mv^2 \quad W = Fs$ (0.5) for both

$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + Fs$

$\frac{1}{2}(85)(7^2) = 0 + (450)(s)$ (1)

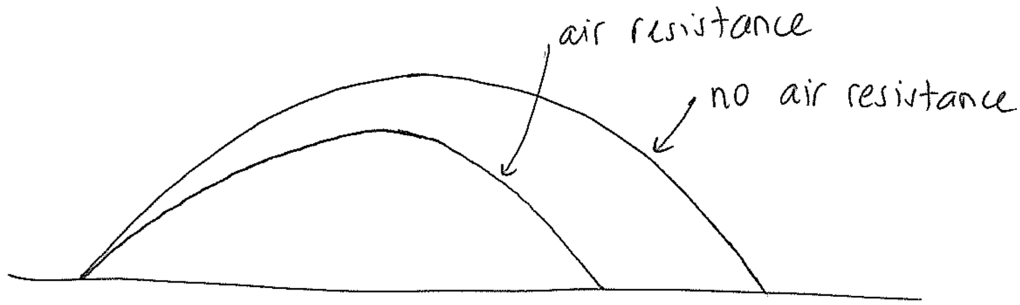
$s = 4.63\ m$ (1)

Question 3 **(6 marks)**

A projectile is fired from ground level and falls back to ground level.

(a) In the space below, sketch the trajectory of the projectile, assuming there is no air resistance.

(1 mark)



(b) On your sketch above, in **a different coloured pen**, sketch the trajectory of the projectile when in the **presence** of air resistance.

(2 marks)

(c) Select and state **one** feature of the two sketches which is different and explain the difference.

(3 marks)

- Maximum height reached
    - Air resistance acts in the opposite direction to motion
    - On the ascent, the net force (in the opposite direction to the motion) is increased (than with no air resistance) and so the projectile decelerates to zero faster and does not reach as great a height.
- Horizontal Range
    - Air resistance acts in the opposite direction to motion
    - On the forwards path, there is now a net force (in the opposite direction to the motion where there was none with no air resistance. The projectile decelerates and does not reach as great a distance.
- Steepness of the descent
    - Air resistance is proportional to speed^2
    - On the descent, the speed of the projectile is increasing, so the air resistance acting against it will increase until terminal velocity is reached. The velocity in the horizontal direction is also decreased and so the gradient of the downwards slope will be steeper.

1 1 1 1

Question 4 **(7 marks)**

A car travels along the curved exit ramp of a freeway. The radius of the curve is 80.0 m and the curve is not banked. A 70.0 kg passenger experiences a force of 220 N during the turn.

(a) What is the car's speed in kmh^{-1}?

(4 marks)

$$F_c = \frac{mv^2}{r}$$

$$220 = \frac{(70)(v^2)}{80}$$

$$v = 15.9\ ms^{-1}$$

$$15.9\ ms^{-1} = 57.2\ kmh^{-1}$$

(b) A passenger in the same car feels as though they are being pushed towards their door. Is this a real force they are experiencing? Explain your reasoning.

(3 marks)

- No, it is not a real force (they experience the force because they are in an accelerating frame of reference).
- According to Newton's 1st law, due to their inertia they continue to travel in a straight line and the car turns underneath them (they perceive this relative motion as a force pushing against them).
- They feel the car moving under them but their brain interprets it as a force pushing them (due to the accelerating frame of reference)

1 F_f 1 1 1 1 1 1 1

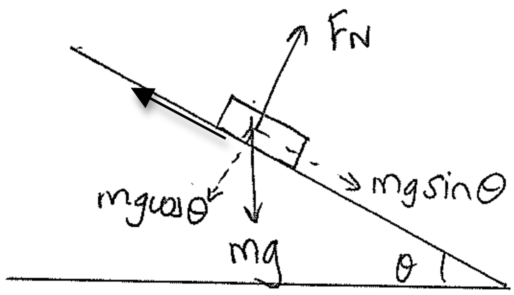
Question 5 **(13 marks)**

A sled weighing 200 N rests on a 15.0° incline. The coefficient of static friction (μ_s) is 0.500.

Given that $F_f = \mu_s F_N$ and $F_f = \mu_k F_N$

(a) Sketch a diagram below showing the forces acting on the sled, including any appropriate resolution of forces.

(4 marks)



(b) Calculate the magnitude of the static friction exerted on the sled.

(4 marks)

$$\Sigma F = ma$$
$$\Sigma F_{perpendicular} = F_N - mg\cos\theta = 0$$
$$F_f = \mu_s (mg\cos\theta)$$
$$= (0.5)(200)(\cos 15)$$
$$= 96.6\ N$$

OR

$$\Sigma F = ma$$
$$\Sigma F_{parallel} = mg\sin\theta - F_f = 0$$
$$F_f = mg\sin\theta$$
$$= (200)(\sin 15)$$
$$= 51.8\ N$$

0.5 1 0.5 0.5 1 0.5 1

(c) A child with a weight of 500 N now sits on the sled. If the coefficient of kinetic friction (μ_k) is 0.150, calculate the acceleration of the sled. You may restate the result of derivations from (b).

(5 marks)

$$F_f = \mu_k mg\cos\theta$$
$$= (0.15)(500+200)(\cos 15)$$
$$= 101\ N$$

$$\Sigma F = ma$$
$$\Sigma F_{parallel} = mg\sin\theta - F_f = ma$$
$$(500+200)(\sin 15) - 101 = \left(\frac{500+200}{9.8}\right)a$$
$$a = 1.12\ ms^{-2}\ down\ the\ slope$$

Start 11

Take-off 1

Question 6 **(11 marks)**

Ski jumping, recently seen at the Winter Olympics in Sochi, is a sport in which skiers go down a take-off ramp, then jump and attempt to impress judges. From the top of the run, it is a vertical drop of 140 m from their starting position to the landing. This is roughly equivalent to a 40-storey fall.

The ski jumper in the diagram above takes off from the ramp with a speed of 90.0 kmh^{-1} at an angle of 12.0° above the horizontal. Assume the take-off point is 21.0 m below the starting position.

(a) Determine the flight time of the ski jumper from the take-off point. (4 marks)

$$90.0\ kmh^{-1} = 25.0\ ms^{-1}$$

$$s = ut + \frac{1}{2}at^2$$

$$-(140-21) = (25\sin 12)(t) + \frac{1}{2}(-9.8)(t^2)$$

$$4.9t^2 - 5.20t - 119 = 0$$

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{5.2 + \sqrt{(4.9^2 - (4)(4.9)(-119))}}{9.8}$$

Or can state using quadratic equation

$$= 5.49\ s$$

-1 mark if not converted to ms^{-1}.

0.5 1 0.5 0.5 0.5 1 0.5 0.5 0.5

(b) Calculate the horizontal displacement of the ski jumper from the take-off point?

(3 marks)

$$s = tv$$
$$= (5.49)(25\cos 12)$$
$$= 134\ m$$

(c) Calculate the velocity of the ski jumper on landing.

(4 mark)

$$v = u + at$$
$$= (25\sin 12) + (-9.8)(5.48)$$
$$= -48.5\ ms^{-1}$$

$$|v| = \sqrt{48.5^2 + (25\cos 12)^2}$$
$$= 54.3\ ms^{-1}$$
$$\tan\theta = \frac{opp}{adj} = \frac{48.5}{25\cos 12}$$
$$\theta = 65.8^\circ$$
$$v = 54.3\ ms^{-1} \quad 63.2^\circ\ below\ the\ horizontal$$

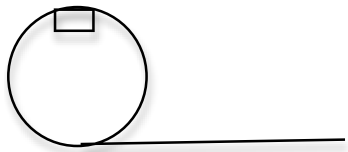
0.5 1 0.5 1

B

Question 7 **(9 marks)**

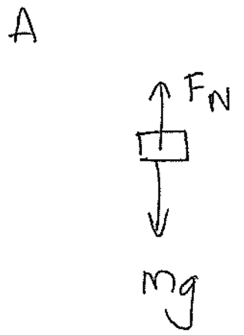
A block slides on a frictionless surface along a loop-the-loop, as shown in the diagram below. The loop-the-loop has a radius of 20.0 cm.

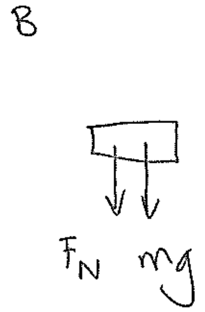
A



(a) In the area below, sketch and label free body diagrams of the forces acting on the block at point A and at point B.

(2 marks)





0.5 mark each arrow and label

(b) If the block was initially released from a point 1.40 m above A, what is the speed of the block at B?

(3 marks)

$$\Sigma E_i = \Sigma E_f$$

$$E_k = \frac{1}{2}mv^2 \quad E_p = mgh$$ for both

$$\frac{1}{2}mu^2 + mgh_i = \frac{1}{2}mv^2 + mgh_f$$

$$0 + (9.8)(1.4) = \frac{1}{2}v^2 + (9.8)(0.4)$$

$$= 4.43\ ms^{-1}$$

(c) By making reference to your answer from (b), show that the block will successfully complete the loop-the-loop, (i.e. that it will never lose contact with the track).

(4 marks)

- block will lose contact with the track if $F_N = 0$ at the top

$$\Sigma F = ma$$
$$\Sigma F = -F_N - mg = -ma_c$$
$$if\ F_N = 0$$
$$mg = \frac{mv^2}{r}$$
$$v = \sqrt{rg}$$
$$= \sqrt{(0.2)(9.8)}$$
$$1.40\ ms^{-1}$$

- The block is travelling at 4.43 ms^{-1} which is greater than the minimum speed at which the block will lose contact with the track.